coastalmanagement

Whareama Estuary

Fine Scale Monitoring 2008/09

Prepared for
Greater Wellington Regional Council
May 2009

Cover Photo: Whareama Estuary - Site WhaA - lower estuary. Inside Photo: Upper Estuary sampling site WhaB.

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By

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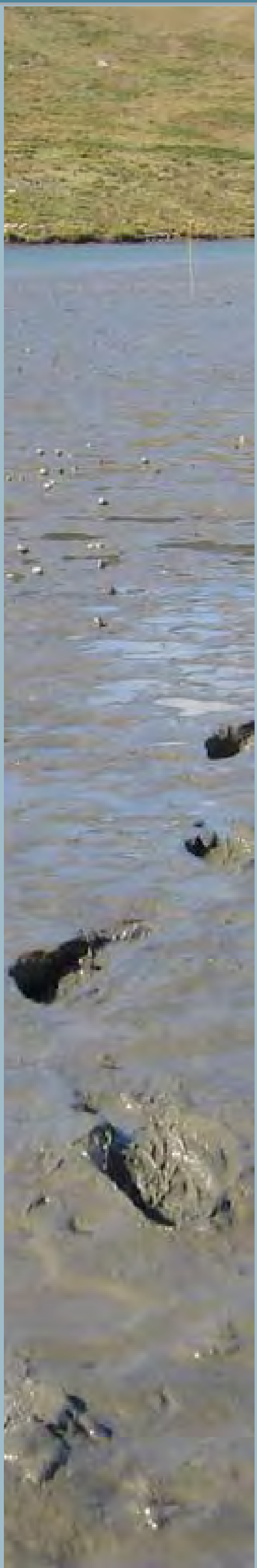
All photos by Wriggle except where noted otherwise.

WHAREAMA ESTUARY - EXECUTIVE SUMMARY



This report summarises the results of the 2009 fine scale monitoring for Whareama Estuary, a 12km long, tidal river estuary on the Wairarapa coast. It is one of the key estuaries in Greater Wellington Regional Council's (GWRC) long-term coastal monitoring programme. The following table summarises results and condition ratings for the two intertidal sites:

Indicator	2008	2009	Result
RPD Depth	Fair	Fair	Redox Potential Discontinuity (RPD) was shallow (1-3cm depth) at both sites in 2008 and 2009, indicating poor oxygenation.
Macrofauna	Good-Mod	Good	The benthic community condition showed a slight improvement in 2009 compared with 2008.
Organic Matter (TOC)	Good	Good	The indicator of organic enrichment (TOC) at both sites was at low concentrations in both 2008 and 2009.
Nutrients (TN and TP)	Low-Mod Enrichment	Low-Mod Enrichment	The indicators of nutrient enrichment (TN and TP) at both sites were low to moderate in both 2008 and 2009.
Sedimentation Rate	Baseline	High	The rate of sedimentation averaged 14.5mm/yr from 2008 to 2009 which fits the "high" condition rating.
Grain Size	No Rating	No Rating	Both sites were dominated by muddy sediments (70% mud) in 2008. In 2009 there was a shift to sandier conditions at each site.
Metals and Pesticides (Cd, Cr, Cu, Ni, Pb, Zn & DDT)	Good-Very Good	Good-Very Good	Heavy metals were at very low concentrations at both sites in both 2008 and 2009, with all values well below the ANZECC (2000) ISQG-Low trigger values. Synthetic organic contaminants (including DDT) were also below detection limits and ANZECC (2000) ISQG-Low trigger values in 2008 (not measured in 2009).

Overall, the second year of fine scale monitoring results showed that the dominant intertidal habitat was generally in good to fair condition. Conditions were similar to those measured in January 2008, but did show some improvements as follows;

- Both sites showed a shift towards less muddy and sandier sediment types. However, this was accompanied by a rapid buildup of sediment height (as measured at the upper site).
- Sediment levels of organic carbon, nitrogen and phosphorus were slightly lower in 2009.
- The benthic invertebrate community condition showed a slight improvement but was still "unbalanced" giving it a "good" classification.

As stated in the 2008 report, the Whareama Estuary is particularly vulnerable to excessive inputs of fine sediments and nutrients causing algal blooms and sediment anoxia. Currently, nutrient enrichment problems are in the low-moderate category in the estuary but sedimentation is excessive.

Future Monitoring

Whareama Estuary has been identified by GWRC as a priority for monitoring, and is a key part of GWRC's coastal monitoring programme being undertaken in a staged manner throughout the Greater Wellington region. The fine scale and sedimentation rate component involves three to four years of scheduled baseline monitoring (2008 to 2011). Thereafter, monitoring is reduced to five yearly intervals or as deemed necessary based on the condition ratings.

Management

The fine scale monitoring results reinforce the need for management of nutrient and fine sediment sources entering the estuary. Source identification plans to minimise their adverse effects on estuary uses (e.g. fishing, boating, swimming, shellfish collection) and values are recommended.

1. INTRODUCTION

OVERVIEW

Developing an understanding of the condition and risks to coastal and estuarine habitats is critical to the management of biological resources. Recently, Greater Wellington Regional Council (GWRC) undertook vulnerability assessments of its region's coastlines to establish priorities for a long-term monitoring programme for the region (Robertson and Stevens 2007b, 2007c and 2007d). These assessments identified the following estuaries as immediate priorities for monitoring: Porirua Harbour, Whareama Estuary, Lake Onoke, Hutt Estuary and Waikanae Estuary. In late 2007, GWRC chose to begin estuary monitoring in a staged manner, with the Porirua Harbour (Onepoto and Pauatahanui Arms) and Whareama Estuary (Wairarapa Coast) as the first estuaries. Wriggle Coastal Management were contracted to undertake the work using the National Estuary Monitoring Protocol (EMP) (Robertson et al. 2002) plus recent extensions (Table 1).

The Whareama Estuary monitoring programme consists of three components:

1. **Ecological Vulnerability Assessment** of the estuary to major issues and appropriate monitoring design. This component has been completed for Whareama Estuary and is reported on in Robertson and Stevens (2007b).
2. **Broad scale habitat mapping** (EMP approach). This component, which documents the key habitats within each estuary and changes to these habitats over time, has been completed for the Whareama Estuary (Robertson and Stevens 2007b).
3. **Fine scale physical, chemical and biological monitoring** (EMP approach), including sedimentation plate deployment. This component, which provides detailed information on the condition of the Whareama Estuary, began in January 2008. The second year of monitoring (January 2009) is the subject of the current report.

Whareama Estuary is a long, narrow, "tidal river" type estuary on the Wairarapa coast. The estuary is relatively shallow (1-3m deep) and enclosed within a steep valley. The estuary margin is dominated by grassland and is generally devoid of saltmarsh vegetation except for a narrow strip in the lower section. The bed of the estuary is dominated by muddy sediments except for the very lowest reaches where firm sands dominate. Saltwater extends up to 12km inland and the waters are particularly turbid. There is an indication of moderate macroalgal blooms and the waters have a distinctive green colouration, probably from high levels of chlorophyll in the water.

The current report documents the following;

- The results of the fine scale and sedimentation rate monitoring of Whareama Estuary intertidal sites (undertaken in January 2009).
- Condition ratings for Whareama Estuary based on the 2009 fine scale results. A suggested monitoring or management response is linked to each condition rating.

This report is the second of a proposed series of three or four, which will characterise the baseline fine scale conditions in the estuary over a three to four year period. The results will help determine the extent to which the estuary is affected by major estuary issues or problems (Table 2), both in the short and long term. The survey focuses on providing detailed information on indicators of physical, chemical and biological condition (Table 3) of the dominant habitat type in the estuary (i.e. unvegetated intertidal mudflats at low-mid water).

1. Introduction (Continued)

Table 1. Coastal Monitoring Tools (Wriggle Coastal Management).

Resource	Tools for Monitoring and Management
Estuaries	Estuary vulnerability matrix. Broad scale estuary and 200m terrestrial margin habitat mapping. Fine scale estuary monitoring. Sedimentation rate measures (using plates buried in sediment). Historical sedimentation rates (using radio-isotope ageing of sediment cores). Macroalgae and seagrass mapping (reported as separate GIS layers). Condition ratings for key indicators. Georeferenced digital photos (as a GIS layer). Upper estuary monitoring and assessment.
Beaches, Dunes	Beach and dune vulnerability matrix. Broad scale beach, dune and terrestrial margin mapping. Fine scale beach monitoring. Condition ratings for key indicators. Georeferenced digital photos (as a GIS layer).
Rocky Shores	Rocky shore vulnerability matrix. Broad scale rocky shore and terrestrial margin mapping. Fine scale rocky shore monitoring. Georeferenced digital photos (as a GIS layer).

Table 2. Summary of the major issues affecting most NZ river mouth estuaries.

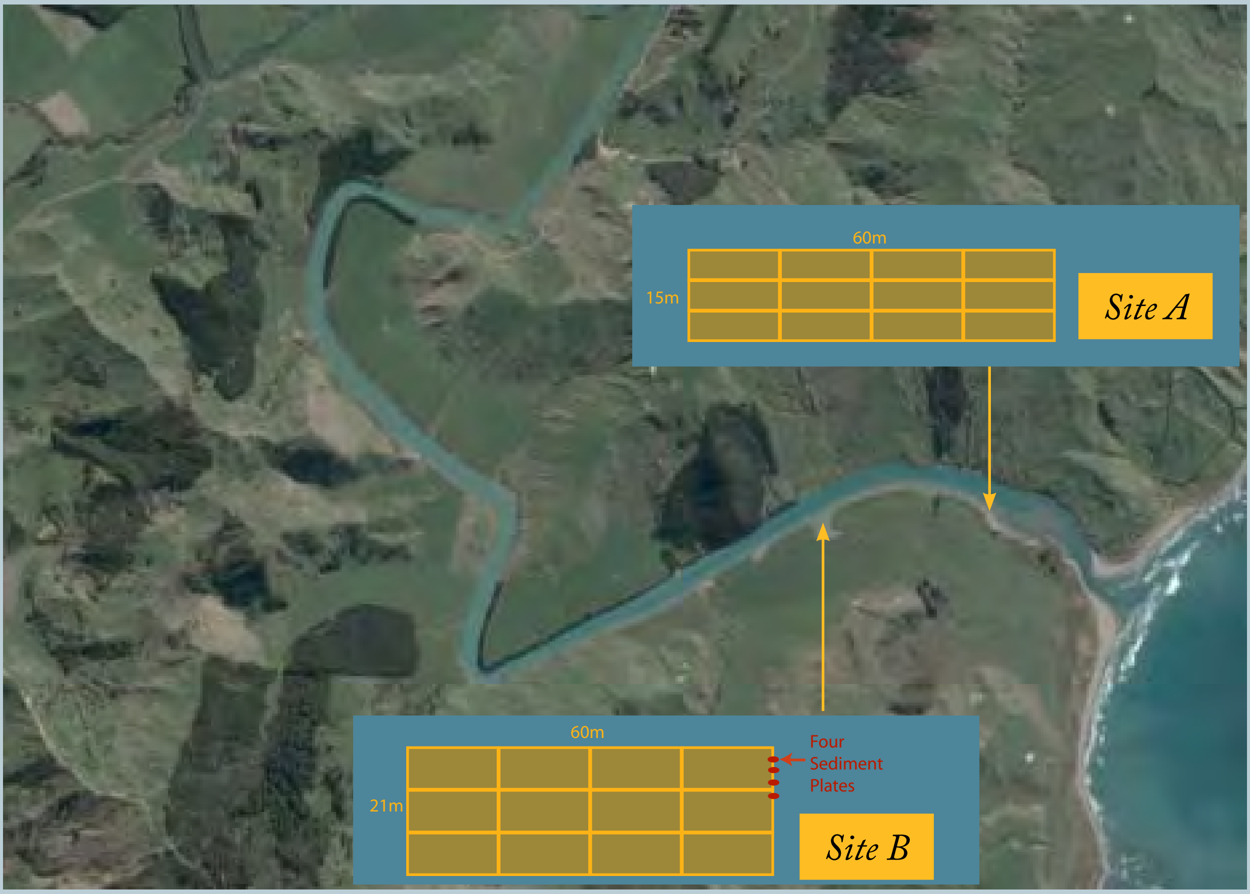
Key Estuary Issues	
Sedimentation	Because estuaries are a sink for sediments, their natural cycle is to slowly infill with fine muds and clays. Prior to European settlement they were dominated by sandy sediments and had low sedimentation rates (<1 mm/year). In the last 150 years, with catchment clearance, wetland drainage, and land development for agriculture and settlements, New Zealand's estuaries have begun to infill rapidly. Today, average sedimentation rates in our estuaries are typically 10 times or more higher than before humans arrived.
Nutrients	Increased nutrient richness of estuarine ecosystems stimulates the production and abundance of fast-growing algae, such as phytoplankton, and short-lived macroalgae (e.g. sea lettuce). Fortunately, because most New Zealand estuaries are well flushed, phytoplankton blooms are generally not a major problem. Of greater concern is the mass blooms of green and red macroalgae, mainly of the genera *Enteromorpha, Cladophora, Ulva,* and *Gracilaria* which are now widespread on intertidal flats and shallow subtidal areas of nutrient-enriched New Zealand estuaries. They present a significant nuisance problem, especially when loose mats accumulate on shorelines and decompose. Blooms also have major ecological impacts on water and sediment quality (e.g. reduced clarity, physical smothering, lack of oxygen), affecting or displacing the animals that live there.
Disease Risk	Runoff from farmland and human wastewater often carries a variety of disease-causing organisms or pathogens (including viruses, bacteria and protozoans) that, once discharged into the estuarine environment, can survive for some time. Every time humans come into contact with seawater that has been contaminated with human and animal faeces, we expose ourselves to these organisms and risk getting sick. Aside from serious health risks posed to humans through recreational contact and shellfish consumption, pathogen contamination can also cause economic losses due to closed commercial shellfish beds. Diseases linked to pathogens include gastroenteritis, salmonellosis, hepatitis A, and noroviruses.
Toxic Contamination	In the last 60 years, New Zealand has seen a huge range of synthetic chemicals introduced to estuaries through urban and agricultural stormwater runoff, industrial discharges and air pollution. Many of them are toxic in minute concentrations. Of particular concern are polycyclic aromatic hydrocarbons (PAHs), heavy metals, polychlorinated biphenyls (PCBs), and pesticides. These chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to people and marine life.
Habitat Loss	Estuaries have many different types of habitats including shellfish beds, seagrass meadows, saltmarshes (rushlands, herbfields, reedlands etc.), forested wetlands, beaches, river deltas, and rocky shores. The continued health and biodiversity of estuarine systems depends on the maintenance of high-quality habitat. Loss of habitat negatively affects fisheries, animal populations, filtering of water pollutants, and the ability of shorelines to resist storm-related erosion. Within New Zealand, habitat degradation or loss is common-place with the major causes cited as sea level rise, population pressures on margins, dredging, drainage, reclamation, pest and weed invasion, reduced flows (damming and irrigation), over-fishing, polluted runoff and wastewater discharges.

1. Introduction (Continued)

Table 3. Summary of the broad and fine scale EMP indicators.

Issue	Indicator	Method
Sedimentation	Soft Mud Area	Broad scale mapping - estimates the area and change in soft mud habitat over time.
Sedimentation	Sedimentation Rate	Fine scale measurement of sediment deposition.
Eutrophication	Nuisance Macroalgal Cover	Broad scale mapping - estimates the change in the area of nuisance macroalgal growth (e.g. sea lettuce (*Ulva*), *Gracilaria* and *Enteromorpha*) over time.
Eutrophication	Organic and Nutrient Enrichment	Chemical analysis of total nitrogen, total phosphorus, and total organic carbon in replicate samples from the upper 2cm of sediment.
Eutrophication	Redox Profile	Measurement of depth of redox potential discontinuity profile (RPD) in sediment estimates likely presence of deoxygenated, reducing conditions.
Toxins	Contamination in Bottom Sediments	Chemical analysis of indicator metals (total recoverable cadmium, chromium, copper, nickel, lead and zinc) in replicate samples from the upper 2cm of sediment.
Toxins, Eutrophication, Sedimentation	Biodiversity of Bottom Dwelling Animals	Type and number of animals living in the upper 15cm of sediments (infauna in 0.0133m^2 replicate cores), and on the sediment surface (epifauna in 0.25m^2 replicate quadrats).
Habitat Loss	Saltmarsh Area	Broad scale mapping - estimates the area and change in saltmarsh habitat over time.
Habitat Loss	Seagrass Area	Broad scale mapping - estimates the area and change in seagrass habitat over time.
Habitat Loss	Vegetated Terrestrial Buffer	Broad scale mapping - estimates the area and change in buffer habitat over time.

Figure 1 Location of sediment plates and fine scale monitoring sites, Whareama Estuary (Photo; Google Earth)



2. METHODS

FINE SCALE MONITORING

Fine scale monitoring is based on the methods described in the EMP (Robertson et al. 2002) and provides detailed information on indicators of chemical and biological condition of the dominant habitat type in the estuary. This is most commonly unvegetated intertidal mudflats at low-mid water. Using the outputs of the broad scale habitat mapping, representative sampling sites (usually two per estuary) are selected and samples collected and analysed for the following variables:

- Salinity, Oxygenation (Redox Potential Discontinuity - RPD), Grain size (% mud, sand, gravel).
- Total organic carbon (TOC).
- Nutrients: Total nitrogen (TN), Total phosphorus (TP).
- Heavy metals: Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb), Nickel (Ni) and Zinc (Zn).
- Macroinvertebrate abundance and diversity (infauna and epifauna)

For the Whareama Estuary, two fine scale sampling sites (Figure 1, Appendix 1), were selected in, mid-low water mudflats (avoiding areas of significant vegetation and channels). At the upper site, a 60m x 21m area (and at the lower site a 60m x 15m area), in the lower intertidal were marked out and divided into 12 equal sized plots. Within each area, ten plots were selected, a random position defined within each, and the following sampling undertaken:

Physical and chemical analyses:

- Within each plot, one random core was collected to a depth of at least 100mm and photographed alongside a ruler and a corresponding label. Colour and texture were described and average RPD depth recorded.
- At each site, three samples (each a composite from four plots) of the top 20mm of sediment (each approx. 250gms) were collected adjacent to each core. All samples were kept in a chillybin in the field.
- Chilled samples were sent to R.J. Hill Laboratories for analysis (details in Appendix 1):
    - Grain size/Particle size distribution (% mud, sand, gravel).
    - Nutrients (TN and TP).
    - Total organic carbon (TOC)
    - Trace metal contaminants (Cd, Cr, Cu, Ni, Pb, Zn). Analyses were based on whole sample fractions which are not normalised to allow direct comparison with the Australian and New Zealand Guidelines for Fresh and Marine Water Quality produced by Australian and New Zealand Environment and Conservation Council (ANZECC 2000).
- Samples were tracked using standard Chain of Custody forms and results are checked and transferred electronically to avoid transcription errors.
- Photographs were taken to record the general site appearance.
- In addition, salinity of the overlying water was measured at low tide at each site.

Epifauna (surface-dwelling animals):

- Epifauna were assessed from one random 0.25m^2 quadrat within each of ten plots. All animals observed on the sediment surface were identified and counted, and any visible microalgal mat development noted. The species, abundance and related descriptive information were recorded on specifically designed waterproof field sheets containing a checklist of expected species. Photographs of quadrats were taken and archived for future reference.

2. METHODS (CONTINUED)

FINE SCALE MONITORING (CONTINUED)

Infauna (animals within sediments):

- One randomly placed sediment core was taken from each of ten plots using a 130mm diameter (area = $0.0133m^2$) PVC tube.
- The core tube was manually driven 150mm into the sediments, removed with the core intact and inverted into a labelled plastic bag.
- Once all replicates had been collected at a site, the plastic bags were transported to a nearby source of seawater and the contents of the core washed through a 0.5mm nylon mesh bag. The infauna remaining were carefully emptied into a plastic container with a waterproof label and preserved in 70% isopropyl alcohol - seawater solution.
- The samples were then transported to a commercial laboratory for counting and identification (Gary Stephenson, Coastal Marine Ecology Consultants).

Sedimentation Plate Deployment:

Determining the sedimentation rate from now and into the future involves a simple method of measuring how much sediment builds up over a buried plate over time. Once a plate has been buried, levelled, and the elevation measured, probes are pushed into the sediment until they hit the plate and the penetration depth is measured. A number of measurements on each plate are averaged to account for irregular sediment surfaces, and a number of plates are buried to account for small scale variance. Locations (Figure 1) and methods for deployment are presented in the 2008 report (Robertson and Stevens 2008).

CONDITION RATINGS

At present, there are no formal criteria for rating the overall condition of estuaries in NZ, and development of scientifically robust and nationally applicable condition ratings requires a significant investment in research and is unlikely to produce immediate answers. Therefore, to help GWRC interpret their monitoring data, a series of interim broad and fine scale estuary "condition ratings" (presented below) have been proposed for the Whareama Estuary (based on the ratings developed for Southland's estuaries - Robertson & Stevens 2006, 2007a).

The condition ratings are designed to be used in combination with each other (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management responses.

The ratings are based on a review of monitoring data, use of existing guideline criteria (e.g. ANZECC (2000) sediment guidelines), and expert opinion. They indicate whether monitoring results reflect good or degraded conditions, and also include an "early warning trigger" so that GWRC is alerted where rapid or unexpected change occurs. For each of the condition ratings, a recommended monitoring frequency is proposed and a recommended management response is suggested.

In most cases the management recommendation is simply that GWRC develop a plan to further evaluate a problem and consider what response actions may be appropriate. It is expected that the proposed ratings will continue to be revised and updated as better information becomes available, and that new ratings will be developed for other indicators. Note that only fine scale ratings are presented in this section. Broad scale ratings are included in Stevens and Robertson (2008).

RATING
Very Good
Good
Fair
Poor
Early Warning Trigger

2. Methods (Continued)

Redox Potential Discontinuity

The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. The RPD marks the transition between oxygenated and reduced conditions and is an effective ecological barrier for most but not all sediment-dwelling species. A rising RPD will force most macrofauna towards the sediment surface to where oxygen is available. In addition, nutrient availability in estuaries is generally much greater where sediments are anoxic, with consequent exacerbation of the eutrophication process.

RPD CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	>10cm depth below surface	Monitor at 5 year intervals after baseline established
Good	3-10cm depth below sediment surface	Monitor at 5 year intervals after baseline established
Fair	1-3cm depth below sediment surface	Monitor at 5 year intervals. Initiate Evaluation & Response Plan
Poor	<1cm depth below sediment surface	Monitor at 2 year intervals. Initiate Evaluation & Response Plan
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Metals

Heavy metals provide a low cost preliminary assessment of toxic contamination in sediments and are a starting point for contamination throughout the food chain. Sediments polluted with heavy metals (poor condition rating) should also be screened for the presence of other major contaminant classes: pesticides, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs).

METALS CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<0.2 x ISQG-Low	Monitor at 5 year intervals after baseline established
Good	<ISQG-Low	Monitor at 5 year intervals after baseline established
Fair	<ISQG-High but >ISQG-Low	Monitor at 2 year intervals and manage source
Poor	>ISQG-High	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Nitrogen

In shallow estuaries like Whareama, the sediment compartment is often the largest nutrient pool in the system, and nitrogen exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL NITROGEN CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<500mg/kg	Monitor at 5 year intervals after baseline established
Low-Mod Enrichment	500-2000mg/kg	Monitor at 5 year intervals after baseline established
Enriched	2000-4000mg/kg	Monitor at 2 year intervals and manage source
Very Enriched	>4000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Phosphorus

In shallow estuaries like Whareama the sediment compartment is often the largest nutrient pool in the system, and phosphorus exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL PHOSPHORUS CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<200mg/kg	Monitor at 5 year intervals after baseline established
Low-Mod Enrichment	200-500mg/kg	Monitor at 5 year intervals after baseline established
Enriched	500-1000mg/kg	Monitor at 2 year intervals and manage source
Very Enriched	>1000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

2. Methods (Continued)

Total Organic Carbon

Estuaries with high sediment organic content can result in anoxic sediments and bottom water, release of excessive nutrients and adverse impacts to biota - all symptoms of eutrophication.

TOTAL ORGANIC CARBON CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<1%	Monitor at 5 year intervals after baseline established
Low-Mod Enrichment	1-2%	Monitor at 5 year intervals after baseline established
Enriched	2-5%	Monitor at 2 year intervals and manage source
Very Enriched	>5%	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Sedimentation Rate

Elevated sedimentation rates are likely to lead to major and detrimental ecological changes within estuary areas that could be very difficult to reverse, and indicate where changes in land use management may be needed.

SEDIMENTATION RATE CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Low	<1mm/yr (typical pre-European rate)	Monitor at 5 year intervals after baseline established
Low	1-5mm/yr	Monitor at 5 year intervals after baseline established
Moderate	5-10mm/yr	Monitor at 5 year intervals after baseline established
High	10-20mm/yr	Monitor yearly. Initiate Evaluation & Response Plan
Very High	>20mm/yr	Monitor yearly. Manage source
Early Warning Trigger	Rate increasing	Initiate Evaluation and Response Plan

Macrofauna Biotic Index

Soft sediment macrofauna can be used to represent benthic community health and provide an estuary condition classification (if representative sites are surveyed). The AZTI (AZTI-Tecnalia Marine Research Division, Spain) Marine Benthic Index (AMBI) (Borja et al. 2000) has been verified successfully in relation to a large set of environmental impact sources (Borja, 2005) and geographical areas (in both northern and southern hemispheres) and so is used here. However, although the AMBI is particularly useful in detecting temporal and spatial impact gradients care must be taken in its interpretation in some situations. In particular, its robustness can be reduced when only a very low number of taxa (1–3) and/or individuals (<3 per replicate) are found in a sample. The same can occur when studying low-salinity locations (e.g. the inner parts of estuaries), some naturally-stressed locations (e.g. naturally organic matter enriched bottoms; *Zostera* beds producing dead leaves; etc.), or some particular impacts (e.g. sand extraction, for some locations under dredged sediment dumping, or some physical impacts, such as fish trawling).

The equation to calculate the AMBI Biotic Coefficient (BC) is a s follows;

$$BC = \{(0 \times \%GI) + (1.5 \times \%GII) + (3 \times \%GIII) + (4.5 \times \%GIV) + (6 \times \%GV)\}/100.$$

The characteristics of the above-mentioned ecological groups (GI, GII, GIII, GIV and GV) are summarised in Appendix 3.

BENTHIC COMMUNITY CONDITION RATING			
ECOLOGICAL RATING	DEFINITION	BC	RECOMMENDED RESPONSE
HIGH	Unpolluted	0-1.2	Monitor at 5 year intervals after baseline established
GOOD	Slightly polluted	1.2-3.3	Monitor 5 yearly after baseline established
MODERATE	Moderately polluted	3.3-5.0	Monitor 5 yearly after baseline est. Initiate ERP
POOR	Heavily polluted	5.0-6.0	Post baseline, monitor yearly. Initiate ERP
BAD	Azoic (devoid of life)	>6.0	Post baseline, monitor yearly. Initiate ERP
Early Warning Trigger	Trend to slightly polluted	>1.2	Initiate Evaluation and Response Plan

3. RESULTS AND DISCUSSION

OUTLINE

A summary of the results of the January 2009 fine scale monitoring of Whareama Estuary is presented in Tables 4 and 5, with detailed results presented in Appendix 2. In order to facilitate understanding, this results and discussion section is divided into three subsections based on the key estuary problems that the fine scale monitoring is addressing: eutrophication, sedimentation, and toxicity. Within each subsection, the results for each of the relevant fine scale indicators are presented (e.g. total nitrogen is presented under the issue of eutrophication). A summary of the condition ratings for each of the two sites is presented in the accompanying figures.

Table 4 Physical and chemical results (means) for Whareama Estuary, 18 Jan 2009 and 18 Jan 2008.

Estuary	Site	Reps	RPD	Salinity	TOC	Mud	Sands	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP
			cm	ppt	%				mg/kg							
Whareama 2009	Wha A	3	1	30	0.39	43.2	56.5	0.45	0.037	9.03	6.93	9.07	6.47	38.33	613	363
	Wha B	3	3	30	0.53	59.6	40.3	0.3	0.041	10.33	8.83	10.33	7.67	43.67	760	410
Whareama 2008	Wha A	3	1.5	30	1.35	67.77	32.07	0.23	0.048	9.17	8.03	6.87	9.90	42.67	780	417
	Wha B	3	2.5	30	1.18	73.43	26.50	0.17	0.050	9.97	8.73	7.70	10.33	47.00	817	430

Table 5 Macrofauna results (means) for Whareama Estuary, 18 Jan 2009 and 18 Jan 2008.

Estuary	Site	Reps	Mean Total Abundance/m^2	Mean Number of Species/Core
Whareama 2009	Wha A	10	7,282	8.1
	Wha B	10	4,365	6
Whareama 2008	Wha A	10	6,400	5.6
	Wha B	10	4,300	4.7

EUTROPHICATION

Eutrophication is the process where water bodies receive excess nutrients that stimulate excessive plant growth. In estuaries like the Whareama, macroalgal (e.g. sea lettuce) and microalgal blooms are the main threat which can lead to sediment anoxia, elevated organic matter and nutrients, increasing muddiness, lowered clarity and benthic community changes. The primary fine scale indicators are therefore grain size, RPD boundary, sediment organic matter, nitrogen and phosphorus concentrations and the community structure of certain sediment-dwelling animals. The broad scale indicators (reported in Robertson and Stevens 2007b) are the percentages of the estuary covered by macroalgae and soft muds.

2008
RPD RATING

Fair

The Redox Potential Discontinuity (RPD)

The depth of the RPD layer is a critical estuary condition indicator in that it provides a measure of whether nutrient enrichment in the estuary exceeds the trigger leading to nuisance anoxic conditions in the surface sediments. The majority of the other indicators (e.g. macroalgal blooms, soft muds, sediment organic carbon, TP, and TN) are less critical, in that they can be elevated, but not necessarily causing sediment anoxia and adverse impacts on aquatic life.

Knowing if the surface sediments are moving towards anoxia (i.e. RPD close to the surface) is important for 2 main reasons:

1. As the RPD layer gets close to the surface, a "tipping point" is reached where the pool of sediment nutrients (which can be large), suddenly becomes available to fuel algal blooms and to worsen sediment conditions.
2. Anoxic sediments contain toxic sulphides and very little aquatic life.

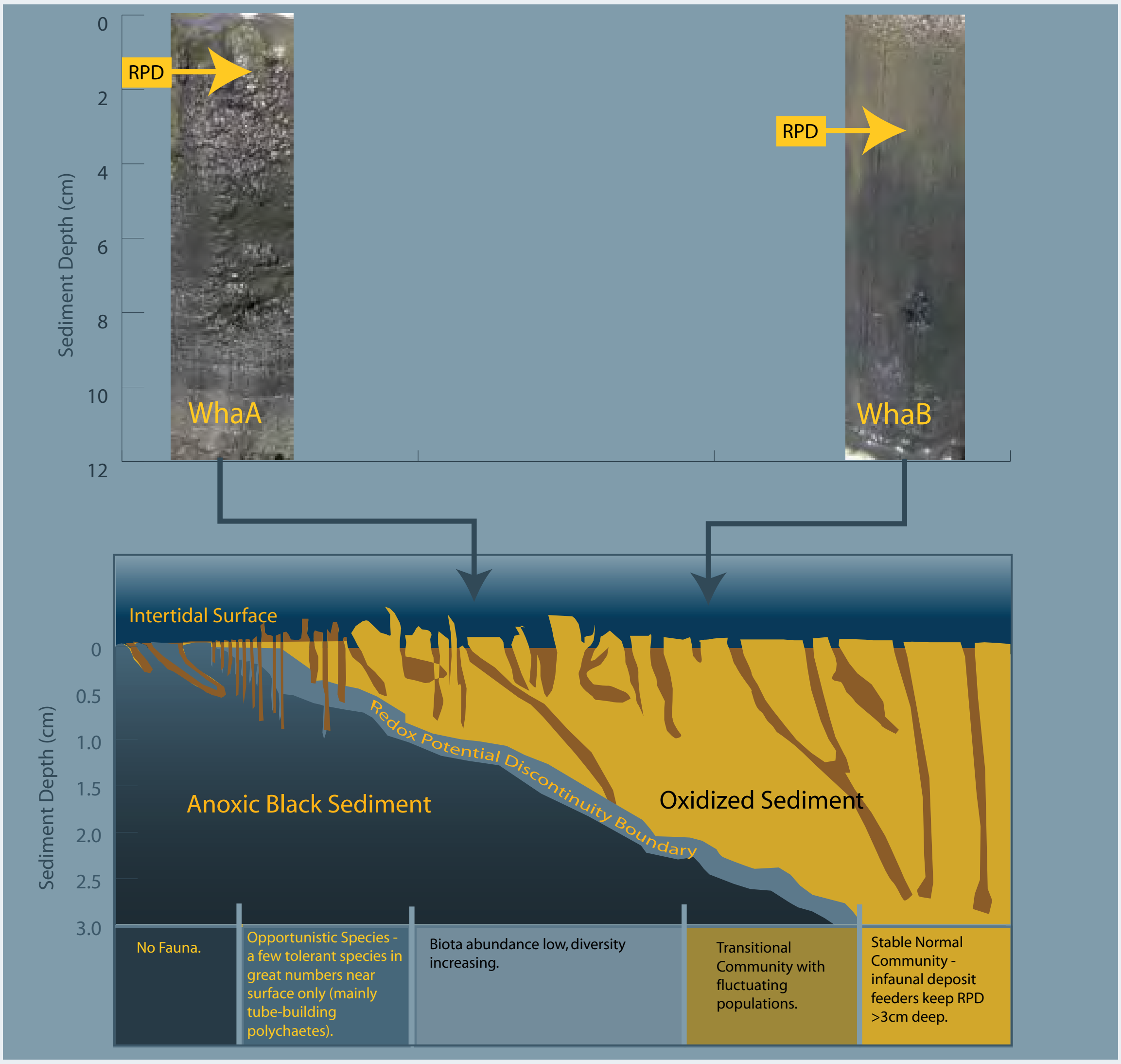
3. Results and Discussion (Continued)

The tendency for sediments to become anoxic is much greater if the sediments are muddy. In sandy porous sediments, the RPD layer is usually relatively deep (>3cm) and is maintained primarily by current or wave action that pumps oxygenated water into the sediments. In finer silt/clay sediments, physical diffusion limits oxygen penetration to <1 cm (Jørgensen and Revsbech 1985) unless bioturbation by infauna oxygenates the sediments.

Figure 2 shows the sediment profiles and RPD depths for each of the two Whareama sampling sites (also Table 4) and indicates the likely benthic community that is supported at each site based on the measured RPD depth (adapted from Pearson and Rosenberg 1978). The results showed that the RPD depth in Whareama Estuary was similar to that measured in 2008, i.e. relatively shallow at 1-3cm depth at both sites and therefore likely to be poorly oxygenated (which was further supported by the facts that infauna feeding voids and burrows were uncommon below the RPD and that sediments were dominated by muds).

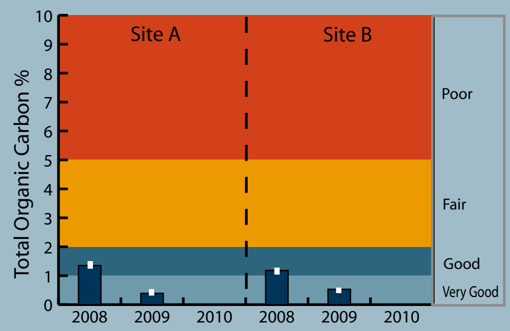
Such shallow RPD values fit the "fair" condition rating and indicate that the benthic invertebrate community was likely to be in an unstable "transitional" state. In addition, because the sediments were dominated by muds but with a significant sand component, it is inferred that sediment aeration was relatively poor [being maintained primarily via bioturbation by benthic invertebrate organisms (subsurface deposit-feeders)].

Figure 2 Sediment profiles, depths of RPD and predicted benthic community type, Whareama Estuary January 2009. Arrows below cores relate to the type of community likely to be found in each core.



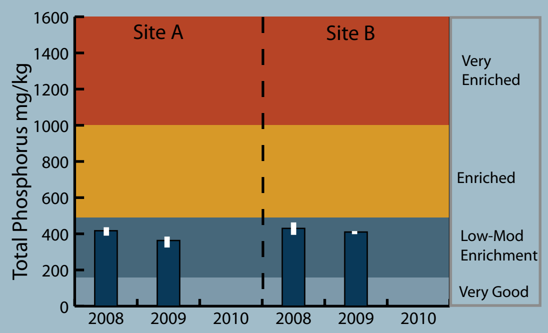
3. Results and Discussion (Continued)

Figure 3. Total organic carbon, (mean and range) Whareama Estuary (2008, 2009).



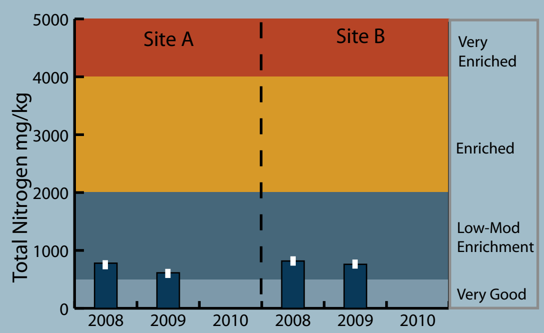
2009 TOC RATING	Very Good

Figure 4. Total phosphorus, (mean and range) Whareama Estuary (2008, 2009).



2009 TP RATING	Low-Mod Enrichment

Figure 5. Total nitrogen, (mean and range) Whareama Estuary (2008-2009).



2009 TN RATING	Low-Mod Enrichment

Organic Matter (TOC) (Figure 3)

Fluctuations in organic input are considered to be one of the principal causes of faunal change in estuarine and near-shore benthic environments. Increased organic enrichment results in changes in physical and biological parameters, which in turn have effects on the sedimentary and biological structure of an area. The number of suspension-feeders (e.g. bivalves and certain polychaetes) decline and deposit-feeders (e.g. opportunistic polychaetes) increase as organic input to the sediment increases (Pearson and Rosenburg 1978).

The indicator of organic enrichment (TOC) at both sites was at moderate to low concentrations (mean 0.46% for 2009) and met the "very good" condition rating. Significantly lower TOC concentrations were measured in 2009 compared with 2008, which are likely to be the result of over-estimation in 2008. In 2008, ash free dry weight and a standard conversion factor were used to estimate TOC. In 2009, TOC was measured directly.

The low TOC levels reflect the generally well-flushed nature of much of the estuary area and a likely moderate load of organic matter (sourced primarily from phytoplankton and macroalgae) depositing on the sediments.

Total Phosphorus (TP) (Figure 4)

Total phosphorus (a key nutrient in the eutrophication process) was present in 2009 at slightly lower concentrations than recorded in 2008, but was still rated in the "low to moderate enrichment" category.

This means that the Whareama Estuary sediments have a low-moderate store of P in the sediments (sourced from both recent and historical catchment inputs).

Fortunately, this store of P is primarily unavailable for fertilising nuisance algal growth, as discussed in 2008 monitoring report (Robertson and Stevens 2008).

Total Nitrogen (TN) (Figure 5)

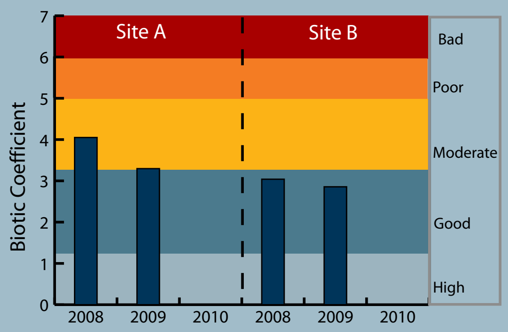
Like phosphorus, total nitrogen (the other key nutrient in the eutrophication process) was present in 2009 at slightly lower concentrations than recorded in 2008, but was still rated in the "low to moderate enrichment" category.

This means that the Whareama sediments have a low-moderate store of N in the sediments (sourced from both recent and historical catchment inputs).

Also as with phosphorus, this store of N is primarily unavailable for fertilising nuisance algal growth, as discussed in 2008 monitoring report (Robertson and Stevens 2008).

3. Results and Discussion (Continued)

Figure 6. Macroinvertebrate rating, sites A and B, 2008, 2009.



2009 Benthic Community RATING	Good

Sediment Biota (Figure 6)

The benthic invertebrate community condition (a key indicator of response to both man-made and natural stressors) in the Whareama Estuary showed a slight improvement in 2009 compared with 2008, which was likely related to the reduction in mud content and the lowered nutrient and organic carbon concentrations. The main change was at Site A, where the condition rating shifted from a "moderate" to a "good" rating for that site.

As in 2008, the 2009 conditions resulted in a community dominated by organisms that prefer moderate mud, shallow RPD, strong salinity fluctuations during floods, and moderate organic enrichment levels. The community comprised primarily small subsurface deposit-feeders (i.e. the bivalve *Arthritica bifurca*, the capitellid polychaete *Heteromastus filiformis* and the spionid polychaete *Scolecolepides benhami*) (Borja et al. 2000, and Thrush et al. 2003).

Compared with the intertidal mudflats in other NZ estuaries, the community diversity was relatively impoverished in 2008 (mean 5-6 species per core - Figure 7) but showed a significant increase in 2009. Mean abundance at each site was low-moderate at 4-7,500 /m^2 (Figure 8).

Figure 7. Mean number of infauna species, Whareama Estuary (2008 and 2009) compared with other NZ estuaries (Source Robertson et al. 2002, Robertson and Stevens 2006).

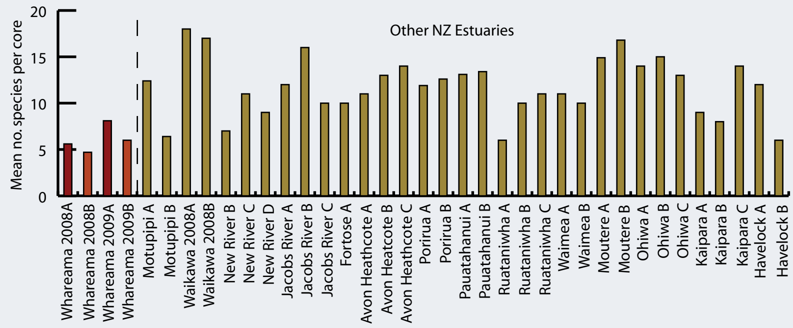
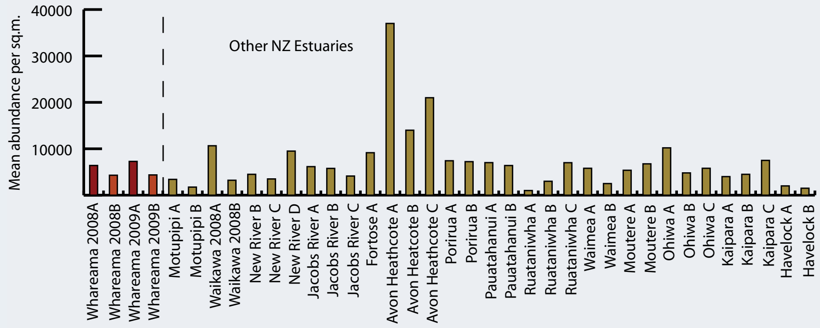


Figure 8. Mean total abundance of macrofauna, Whareama Estuary (2008 and 2009) compared with other NZ estuaries.



TOXICITY

2009 TOXICITY RATING
Good
Very Good

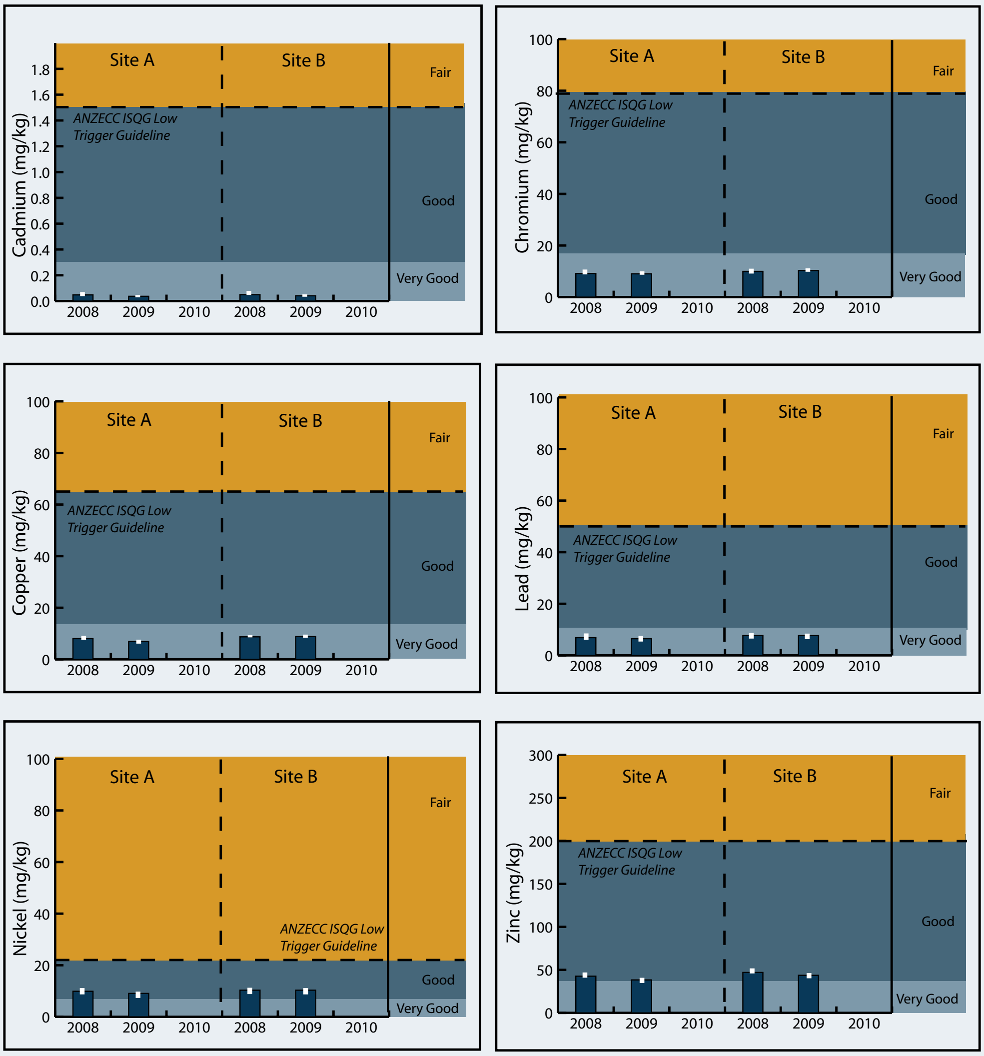
Heavy metals (Cd, Cr, Cu, Ni, Pb, Zn), used as an indicator of potential toxicants, were at low to very low concentrations at both intertidal sites in 2008 and 2009, with all values well below the ANZECC (2000) ISQG-Low trigger values (Figure 9).

Metals met the "very good" condition rating for cadmium, chromium, copper and lead at all sites, and nickel and zinc met the "good" condition rating.

Organochlorine pesticide and polychlorinated biphenyls (PCB's) were measured in 2008 and were all below detection limits and ANZECC (2000) criteria (Robertson and Stevens 2008).

These results indicate that there is no widespread toxicity in the Whareama Estuary.

Figure 9. Sediment metal concentrations, (mean and range) Whareama Estuary (2008, 2009).



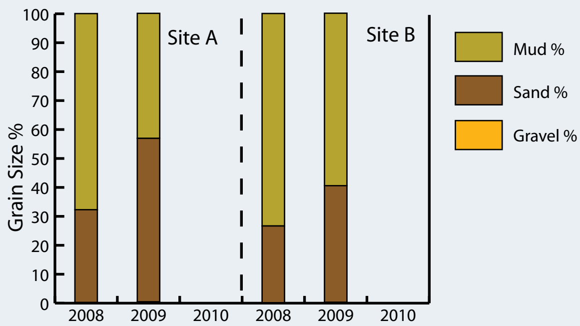
3. Results and Discussion (Continued)

SEDIMENTATION OF FINE SEDIMENT

Soil erosion is a major issue in New Zealand and the resulting suspended sediment impacts are of particular concern in “tidal lagoon” estuaries because they have a central basin which forms a sink for fine sediments. However in “tidal river” estuaries like the Whareama, which is narrow and shallow, there are few sheltered areas for mud to accumulate. High river flows tend to wash a lot of the suspended solid load out to sea, but because the catchment is particularly erosion-prone, much of the estuary bed is muddy and water clarity is low. The primary fine scale indicators of fine sediment deposition are grain size and sedimentation rate. The broad scale indicator is the area of soft mud (see Robertson and Stevens 2007b).

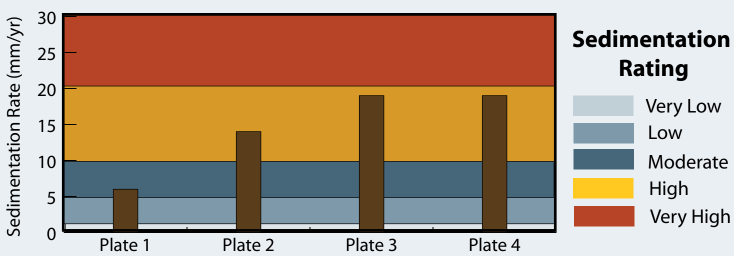
Grain Size (Figure 10)
Grain size (% mud, sand, gravel) measurements provide a good indication of the muddiness of a particular site. The 2008 monitoring results show that all sites were dominated by muddy sediments (approximately 70% mud). The most recent 2009 results, however, show a significant decrease in mud content at both sites (43% mud at Site A and 59% mud at Site B).

Figure 10. Grain size January 2008 and January 2009, Whareama Estuary.

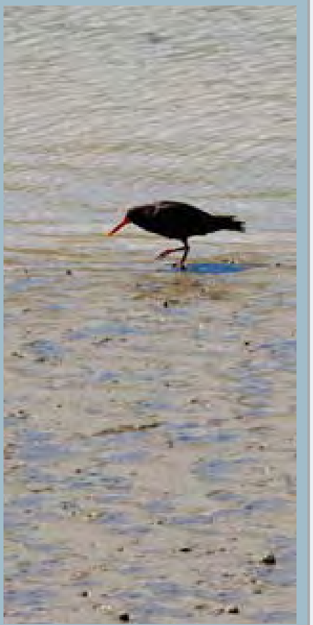


Rate of Sedimentation
Four sedimentation plates were deployed in the estuary in January 2008 (Figure 1) to enable long term monitoring of sedimentation rates. The plates were located in a line at right angles to the river channel. Plate 1 was located 6m from the channel at low water, Plate 2 at 8m, Plate 3 at 10m and Plate 4 at 12m. Monitoring of the overlying sediment depth above each plate after one year of burial indicated a mean sedimentation rate of 14.5 mm/yr. The highest rates (19mm/yr) were recorded at Plates 3 and 4 (i.e. closest to the river channel) whilst the lowest rate (6 mm/yr) was recorded at Plate 1 (i.e. furthest from the channel) (Appendix 2). In terms of condition ratings, such rates place the Whareama Estuary in the “high” sedimentation rate category (Figure 11). However, it will remain to be seen if such high rates are maintained in the longer term.

Figure 11. Sedimentation rate January 2008 to January 2009, Whareama Estuary.



4. SUMMARY



The second year of fine scale monitoring results for a range of physical, chemical and biological indicators of estuary condition show that the dominant intertidal habitat (i.e. unvegetated tidal-flat) in the Whareama Estuary was generally in good to moderate condition. Conditions were similar to those measured one year previously in January 2008, but did show some changes as follows;

- Both sites showed a shift towards less muddy and sandier sediment types. However, this was accompanied by a rapid buildup of sediment height (as measured at the upper site).
- Sediment levels of organic carbon, nitrogen and phosphorus were slightly lower in 2009.
- The benthic invertebrate community condition showed a slight improvement but was still "unbalanced" giving it a "good" classification.

In terms of the eutrophication indicators, the results were in the low-moderate category for nutrients (TN and TP) and organic content, however the sediments were muddy (43-60% mud) and poorly oxygenated as inferred from the relatively shallow RPD layer at all sites (1-3cm). Such conditions provided less favourable habitat for biota and as a consequence the benthic community condition was unbalanced, giving it a "slightly polluted" or "good" classification. In addition, early indications of the estuary sedimentation rate suggest that it is in the "high" category.

As stated in the 2008 report, the Whareama Estuary is vulnerable to excessive inputs of fine sediments and nutrients causing algal blooms and sediment anoxia. Currently, such nutrient enrichment problems are in the low-moderate category in the estuary but sedimentation is excessive.

5. MONITORING

Whareama Estuary has been identified by GWRC as a priority for monitoring, and is a key part of GWRC's coastal monitoring programme being undertaken in a staged manner throughout the greater Wellington region. Based on the 2008 and 2009 monitoring results and condition ratings, it is recommended that monitoring continue as outlined below:

Fine Scale Monitoring (including sedimentation rate). Complete the three to four years of the scheduled baseline monitoring in Whareama Estuary to Jan 2011. After the baseline is completed, reduce monitoring to five yearly intervals or as deemed necessary based on the condition ratings.

6. MANAGEMENT

The fine scale monitoring results reinforced the need for management of nutrient and fine sediment sources entering the estuary. It is recommended that sources of elevated loads in the catchment be identified and management undertaken to minimise their adverse effects on estuary uses and values.

7. ACKNOWLEDGEMENTS

This survey and report has been undertaken with help from various people, local residents (particularly Glen and Angie Meredith from Orui Station) who provided access to the estuary, Maz Robertson for editing, and lastly the staff of Greater Wellington Regional Council who made it all happen. In particular, the support and feedback of Juliet Milne (GWRC) was much appreciated.

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APPENDIX 1. DETAILS ON ANALYTICAL METHODS

Indicator	Laboratory	Method	Detection Limit
Infauna Sorting and ID	CMES	Coastal Marine Ecology Consultants (Gary Stephenson) *	N/A
Grain Size	R.J Hill	Air dry (35 degC, sieved to pass 2mm and 63um sieves, gravimetric - (% sand, gravel, silt)	N/A
Total Organic Carbon	R.J Hill	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	0.05g/100g dry wgt
Total recoverable cadmium	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.01 mg/kg dry wgt
Total recoverable chromium	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable copper	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable nickel	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.2 mg/kg dry wgt
Total recoverable lead	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.04 mg/kg dry wgt
Total recoverable zinc	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	0.4 mg/kg dry wgt
Total recoverable phosphorus	R.J Hill	Nitric/hydrochloric acid digestion, ICP-MS (low level) USEPA 200.2.	40 mg/kg dry wgt
Total nitrogen	R.J Hill	Catalytic combustion, separation, thermal conductivity detector (Elementary Analyser).	500 mg/kg dry wgt

* Coastal Marine Ecology Consultants (established in 1990) specialises in coastal soft-shore and inner continental shelf soft-bottom benthic ecology. Principal, Gary Stephenson (BSc Zoology) has worked as a marine biologist for more than 25 years, including 13 years with the former New Zealand Oceanographic Institute, DSIR. Coastal Marine Ecology Consultants holds an extensive reference collection of macroinvertebrates from estuaries and soft-shores throughout New Zealand. New material is compared with these to maintain consistency in identifications, and where necessary specimens are referred to taxonomists in organisations such as NIWA and Te Papa Tongarewa Museum of New Zealand for identification or cross-checking.

APPENDIX 2. 2009 DETAILED RESULTS

Station Locations

Whareama A	1	2	3	4	5	6	7	8	9	10
NZMGEAST	2770710	2770694	2770682	2770668	2770661	2770673	2770685	2770702	2770698	2770691
NZMGNORTH	6017073	6017081	6017087	6017089	6017088	6017083	6017077	6017070	6017065	6017068

Whareama B	1	2	3	4	5	6	7	8	9	10
NZMGEAST	2770091	2770080	2770052	2770053	2770070	2770076	2770095	2770101	2770086	2770074
NZMGNORTH	6017048	6017044	6017030	6017019	6017029	6017035	6017045	6017038	6017030	6017024

Physical and chemical results for Whareama Estuary, 18 January 2009.

Site	Reps*	RPD	Salinity	TOC	Mud	Sands	Gravel	Cd	Cr	Cu	Ni	Pb	Zn	TN	TP
		cm	ppt	%				mg/kg							
WhaA	1-4	1	30	0.51	51.7	48.3	< 0.1	0.045	10	8.3	10	7.3	42	710	390
WhaA	5-8	1	30	0.34	39.8	60.1	0.1	0.035	8.9	6.7	8.9	6.4	38	590	340
WhaA	9-10	1	30	0.32	38.2	61	0.8	0.032	8.2	5.8	8.3	5.7	35	540	360
WhaB	1-4	3.5	30	0.53	60.4	39.6	< 0.1	0.039	10	8.8	10	7.5	44	750	410
WhaB	5-8	3	30	0.47	56	43.9	< 0.1	0.04	10	8.3	10	7.6	42	710	410
WhaB	9-10	2	30	0.59	62.4	37.3	0.3	0.045	11	9.4	11	7.9	45	820	410

* composite samples

Sediment Plate Depths (mm).

Estuary	Site	18 January 2008	18 January 2009	Sed. Rate (mm/13mths)
Whareama	Plate 1	182	188	6
	Plate 2	156	170	14
	Plate 3	215	234	19
	Plate 4	216	235	19

APPENDIX 2. 2008 DETAILED RESULTS (CONTINUED)

Epifauna (numbers per 0.25m² quadrat)

Whareama A										
Station	Wha A-01	Wha A-02	Wha A-03	Wha A-04	Wha A-05	Wha A-06	Wha A-07	Wha A-08	Wha A-09	Wha A-10
Austrovenus stutchburyi cockle		1				1		1		
No. species/quadrat	0	1	0	0	0	1	0	1	0	0
No. individuals/quadrat	0	1	0	0	0	1	0	1	0	0

Infauna (numbers per 0.01327m² core) (Note NA = Not Assigned)

Whareama A												
Group	**Species**	AMBI Group	Wha A-01	Wha A-02	Wha A-03	Wha A-04	Wha A-05	Wha A-06	Wha A-07	Wha A-08	Wha A-09	Wha A-10
ANTHOZOA	*Anthozoa sp.1*	II				1						
POLYCHAETA	*Boccardia (Paraboccardia) syrtis*	I				2	1		2			
	Ceratonereis sp.1	II					1					1
	Cirratulidae sp.1	IV										
	Glycera lamellipodia	II			1				1			
	Heteromastus filiformis	IV	31	31	52	34	11	11	9	19	3	2
	Nicon aestuariensis	III					4		4	2		
	Perinereis vallata	III	1	2	2			1			2	1
	Scolecolepides benhami	III	10	7	9	6	48	37	44	19	34	30
	Spionidae sp.1	NA	1	3	9	11	8	1	15	2		1
GASTROPODA	*Amphibola crenata*	NA	1									
	Cominella glandiformis	NA		1								
BIVALVIA	*Arthritica* sp.1	III	13	42	19	134	72	15	24	43	27	21
	Austrovenus stutchburyi	I	2					1		1	1	
	Cyclomactra ovata	I									1	
	Macomona liliana	I										
CRUSTACEA	Amphipoda sp.1	NA						1	1			1
	Copepoda sp.1	NA						1				
	Halicarcinus whitei	NA				1						
	Macrophthalmus hirtipes	NA	3	2		2	1		2		2	1
	Palaemonidae sp.1	NA										
	Tenagomysis sp.1	NA	1	1				1	2		2	1
INSECTA	Diptera sp.1	NA										
Total species in sample			9	8	6	8	8	9	10	6	8	9
Total individuals in sample			63	89	92	191	146	69	104	86	72	59

APPENDIX 2. 2008 DETAILED RESULTS (CONTINUED)

Epifauna (numbers per 0.25m² quadrat)

Whareama B										
Station	WhaB-01	WhaB-02	WhaB-03	WhaB-04	WhaB-05	WhaB-06	WhaB-07	WhaB-08	WhaB-09	WhaB-10
Amphibola crenata Mud snail			2				1	1		
No. species/quadrat	0	0	2	0	0	0	1	1	0	0
No. individuals/quadrat	0	0	2	0	0	0	1	1	0	0

Infauna (numbers per 0.01327m² core) **(Note NA = Not Assigned)**

Whareama B												
Group	**Species**	AMBI Group	Wha B-01	Wha B-02	Wha B-03	Wha B-04	Wha B-05	Wha B-06	Wha B-07	Wha B-08	Wha B-09	Wha B-10
ANTHOZOA	*Anthozoa sp.#1*	II										
POLYCHAETA	*Boccardia (Paraboccardia) syrtis*	I										
	Ceratonereis sp.#1	II	1					1			1	1
	Cirratulidae sp.#1	IV										
	Glycera lamellipodia	II										
	Heteromastus filiformis	IV	1		2		2		2			
	Nicon aestuariensis	III	1	2		1				1		
	Perinereis vallata	III	1		1						1	1
	Scolecolepides benhami	III	15	12	14	17	1	8	18	15	24	18
	Spionidae sp.#1	NA										
GASTROPODA	*Amphibola crenata*	NA										
	Cominella glandiformis	NA						4			1	2
BIVALVIA	*Arthritica* sp.#1	III	59	10	17	16	26	16	41	22	100	37
	Austrovenus stutchburyi	I	1		2	1	18		1	1		1
	Cyclomactra ovata	I	1									
	Macomona liliana	I					1					
CRUSTACEA	Amphipoda sp.#1	NA										
	Copepoda sp.#1	NA										
	Halicarcinus whitei	NA										
	Macrophthalmus hirtipes	NA	1		1			1	1			1
	Palaemonidae sp.#1	NA								1		
	Tenagomysis sp.#1	NA	4	3					3		24	1
INSECTA	Diptera sp.#1	NA									1	
Total species in sample			10	4	6	4	5	5	6	5	7	8
Total individuals in sample			85	27	37	35	48	30	66	40	152	62

APPENDIX 3. INFAUNA CHARACTERISTICS

Group and Species		AMBI Group	Details
	Anthozoa sp.1	II	Unidentified anemone.
Polychaeta	*Boccardia (Paraboccardia) syrtis*	I	A small surface deposit-feeding spionid. Prefers low-mod mud content but found in a wide range of sand/mud. It lives in flexible tubes constructed of fine sediment grains, and can form dense mats on the sediment surface. Very sensitive to organic enrichment and usually present under unenriched conditions.
Polychaeta	*Ceratonereis* sp 1	II	A nereid (ragworm) that has most likely been introduced to NZ.
Polychaeta	*Glycera lamellipoda*	II	Glyceridae (blood worms) are predators and scavengers. They are typically large, and are highly mobile throughout the sediment down to depths of 15cm. They are distinguished by having 4 jaws on a long eversible pharynx. Intolerant of anoxic conditions. Often present in muddy conditions. Intolerant of low salinity.
Polychaeta	*Nicon aestuariensis*	III	A nereid (ragworm) that is tolerant of freshwater and is a surface deposit feeding omnivore. Prefers to live in moderate to high mud content sediments.
Polychaeta	*Scolecolepides benhami*	III	A surface deposit feeder. Is rarely absent in sandy/mud estuaries, often occurring in a dense zone high on the shore, although large adults tend to occur further down towards low water mark. Prefers low-moderate mud content (<50% mud). A close relative, the larger *Scolecolepides freemani* occurs upstream in some rivers, usually in sticky mud in near freshwater conditions.
Polychaeta	*Perinereis vallata*	III	An intertidal soft shore nereid (which are common and very active, omnivorous worms). Prefers sandy sediments.
Polychaeta	Spionidae sp.1	NA	An unknown spionid polychaete.
Polychaeta	Cirratulidae sp.1	IV	Subsurface deposit feeder that prefers muddy sands. Small sized, tolerant of slight to unbalanced situations.
Polychaeta	*Heteromastus filiformis*	IV	Small sized capitellid polychaete. A sub-surface deposit-feeder that lives throughout the sediment to depths of 15cm, and prefers a muddy-sand substrate. Despite being a capitellid, *Heteromastus* is not opportunistic and does not show a preference for areas of high organic enrichment as other members of this polychaete group do.
Gastropoda	*Amphibola crenata*	NA	A pulmonate gastropod endemic to New Zealand. Common on a variety of intertidal muddy and sandy sediments. A detritus or deposit feeder, it extracts bacteria, diatoms and decomposing matter from the surface sand. It egests the sand and a slimy secretion that is a rich source of food for bacteria.
Gastropoda	*Cominella glandiformis*	NA	Endemic to NZ. A carnivore living on surface of sand and mud tidal flats. Has an acute sense of smell, being able to detect food up to 30 metres away, even when the tide is out. Intolerant of anoxic surface muds.
Bivalvia	*Arthritica sp.#1*	III	A small sedentary deposit feeding bivalve, preferring a moderate mud content. Lives greater than 2cm deep in the muds.
Bivalvia	*Austrovenus stutchburyi*	NA	The cockle is a suspension feeding bivalve with a short siphon - lives a few cm from sediment surface at mid-low water situations. Can live in both mud and sand but is sensitive to increasing mud - prefers low mud content. Rarely found below the RPD layer.
Bivalvia	*Cyclomactra (Mactra) ovata*	NA	Trough shell of the family Mactridae, endemic to New Zealand. It is found intertidally and in shallow water, deeply buried in soft mud in estuaries and tidal flats. The shell is large, thin, roundly ovate and inflated, without a posterior ridge. The surface is almost smooth. It makes contact with the surface through its breathing tubes which are long and fused. It feeds on minute organisms and detritus floating in the water when the tide covers the shell's site.
Bivalvia	*Macomona liliana*	NA	A deposit feeding wedge shell. This species lives at depths of 5–10cm in the sediment and uses a long inhalant siphon to feed on surface deposits and/or particles in the water column. Rarely found beneath the RPD layer.

APPENDIX 3. INFAUNA CHARACTERISTICS

Group and Species		AMBI Group	Details
Crustacea	Amphipoda sp.	NA	An unidentified amphipod.
	Copepoda	NA	Copepods are a group of small crustaceans found in the sea and nearly every freshwater habitat and they constitute the biggest source of protein in the oceans. Usually having six pairs of limbs on the thorax. The benthic group of copepods (Harpactacoida) have worm-shaped bodies.
	Halicarcinus whitei	NA	Another species of pillbox crab. Lives in intertidal and subtidal sheltered sandy environments.
	Macrophthalmus hirtipes	NA	The stalk-eyed mud crab is endemic to New Zealand and prefers water-logged areas at the mid to low water level. Makes extensive burrows in the mud. Tolerates moderate mud levels. This crab does not tolerate brackish or fresh water (<4ppt). Like the tunneling mud crab, it feeds from the nutritious mud.
	Halicarcinus whitei	NA	Another species of pillbox crab. Lives in intertidal and subtidal sheltered sandy environments.
	Palaemonidae		Palaemonidae is a family of shrimp of the order Decapoda.
	Tenagomysis sp.		A mysid shrimp species.
Insecta	Diptera sp.1	NA	Fly or midge larvae - species unknown.

AMBI Sensitivity to Stress Groupings (from Borja et al. 2000)

Group I. Species very sensitive to organic enrichment and present under unpolluted conditions (initial state). They include the specialist carnivores and some deposit-feeding tubicolous polychaetes.

Group II. Species indifferent to enrichment, always present in low densities with non-significant variations with time (from initial state, to slight unbalance). These include suspension feeders, less selective carnivores and scavengers.

Group III. Species tolerant to excess organic matter enrichment. These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalance situations). They are surface deposit-feeding species, as tubicolous spionids.

Group IV. Second-order opportunistic species (slight to pronounced unbalanced situations). Mainly small sized polychaetes: subsurface deposit-feeders, such as cirratulids.

Group V. First-order opportunistic species (pronounced unbalanced situations). These are deposit-feeders, which proliferate in reduced sediments.

The distribution of these ecological groups, according to their sensitivity to pollution stress, provides a Biotic Index with 5 levels, from 0 to 6.